U.S. Government Open Internet Access to Sub-meter Satellite Data

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The National Geospatial-Intelligence Agency (NGA) has contracted United States commercial remote sensing companies GeoEye and Digital Globe to provide very high resolution commercial quality satellite imagery to federal/state government agencies and those projects/people who support government interests. Under NextView contract terms, those engaged in official government programs/projects can gain online access to NGA's vast global archive. Additionally, data from vendor's archives of IKONOS-2 (IK-2), OrbView-3 (OB-3), GeoEye-1 (GE-1), QuickBird-1 (QB-1), WorldView-1 (WV-1), and WorldView-2 (WV-2), sensors can also be requested under these agreements. We report here the current extent of this archive, how to gain access, and the applications of these data by Earth science investigators to improve discoverability and community use of these data.

Satellite commercial quality imagery (CQI) at very high resolution (< 1 m) (here after referred to as CQI) over the past decade has become an important data source to U.S. federal, state, and local governments for many different purposes. Near global wall-to-wall sub-meter coverage is now available when combining all the archives of U.S. CQI sensors. A coordinated effort was needed to reduce and/or remove image acquisition costs from duplication of requests made by multiple government agencies. The National Geospatial Intelligence Agency (NGA) has been appointed to acquire and archive data from vendors to eliminate duplication costs between government organizations. NGA has developed a system to request, archive, and distribute CQI data to all federal agencies. NGA assists all federal branches, departments, agencies and offices to acquire and use CQI at no cost to the supported organization and has developed a series of contracts with GeoEye and DigitalGlobe. OB-3 is no longer operational, but it collected data from 2003 – 2007 (> 180,000 images) and is currently available for free through the United States Geological Survey (USGS) EarthExplorer (earthexplorer.usgs.gov) and will not be discussed in detail. The first contract between NGA and commercial vendors was ClearView which began in 2003, followed by NextView from 2007 - 2010, and currently EnhancedView from 2012 - 2018. These contracts have provided the ability for U.S. government to investigate changes in the Earth's surface at sub-meter resolution through a negotiated bulk purchase of data.

The rapid growth of free global CQI data has been slow to disseminate to NASA Earth Science community and programs such as the Land-Cover Land-Use Change (LCLUC) program, which sees potential benefit from unprecedented access. This article evolved from a workshop held on February 23rd, 2012 between representatives from NGA, NASA, and NASA LCLUC Scientists discussion on how to extend this resource to a broader license approved community. Many investigators are unaware of NGA's archive availability or find it difficult to access CQI data from NGA. Results of studies, both quality and breadth, could be improved with CQI data by combining them with other moderate to coarse resolution passive optical Earth observation remote sensing satellites, or with RADAR or LiDAR instruments to better understand Earth system dynamics at the scale of human activities. We provide the evolution of this effort, a guide for qualified user access, and describe current to potential use of these data in earth science.

Who Can Access Data?

The current NextView license agreement states that CQI data can be used by all branches, departments and offices of the U.S. Government. With appropriate approval and acknowledgement from NGA, data can also be shared with non-governmental organizations (NGOs), state and local governments, intergovernmental agencies, as well as universities and foreign governments if the use is in support of U.S. government interests when approved by an official legal representative at NGA. Users of CQI must store it offline to ensure it is not openly shared or distributed. All use of CQI must have the appropriate licensing acknowledgements displayed, for example "2012 GeoEYE NextView".

NGA's online interface to access CQI data is called the web based access and retrieval portal (WARP). WARP provides internet access to NGA's Unclassified St. Louis Information Library (USTIL). This library is a subset of the vendor archive from prior government agency requests. To gain WARP access users must have a .gov email address and have public key infrastructure (PKI) that allows secure communication on an insecure public network. Users can register for an account via the WARP website (https://warp.nga.mil), and users must have an ftp server for data from WARP to be pushed to from NGA.

Data in WARP are provided from vendors in National Imagery Transit Format (NITF), a standard Department of Defense (DoD) format. NITF data are stored in compressed format and metadata of sensor/solar/target/geometry information is imbedded within layers of the file. Most image processing software packages can read NITF at no additional cost to the user, although freely available open source tools from GDAL (Geospatial Data Abstraction Library) can be used to convert NITF to more commonly used geospatial tagged image format (Geotiff).

Additional imagery collected by the vendors archive not available in WARP, can be requested through an online USGS interface Commercial Remote Sensing Space Policy (CRSSP) Imagery Derived Requirements (CIDR) tool. CIDR registration and requests can be submitted via the CIDR website (https://cidr.cr.usgs.gov/). A form must be provided that is subject for approval, including project title description and justification. The USGS currently acts as a conduit for civilian agency data requests through NGA's EnhancedView contract. More information about CIDR can be found on the website.

These data support many different U.S. agencies, although immediate access to WARP is limited to those with .gov email addresses. Other users include federally funded scientists from Universities, NGO's, state and local governments who do not have a federal email account and have not been granted special access. NASA is currently exploring options to support NASA's Land-Cover Land-Use Change, Biodiversity, and Cryosphere science communities providing access the commercial archive data for its investigators. Data for NASA program scientists are coordinated to ease access to WARP/CIDR and are placed on a secure NASA server for download.

NGA WARP Data Volume

Density of coverage varies by region, with multi-date time series coverage typically limited to urban areas, or areas of long-term interest from customers of CQI data. All sensors have the ability to point off vertical at targets of interest, and this has negative implications to systematic wall-to-wall acquisition. Capacity is increasing rapidly, although annual time-series acquisitions are currently rare in the archive outside of urban locations. Long-term hotspots of environmental change such as tropical deforestation are not well represented in the archive. This is due to both limited cloud free observations, and lack of a supporting acquisition strategy.

Greater than one half of the WARP archive is post 2007 WV-1 panchromatic imagery due to WV-1's on board storage and downlink capacity that supersedes any other U.S. commercial sensor. WARP was developed primarily for Department of Defense (DoD) users who do not require scientific quality multi-spectral surface reflectance data. Archived imagery is primarily raw at-sensor radiance and not spatially corrected for terrain artifacts (orthorectified). This reduces viability for ecosystem studies, although new methods and algorithms continually evolve to enable these data to be pan-sharpened or fused with other multispectral sensors [*Ehlers*, 2008]. Image processing software also can readily read NITF CQI data and require only a DEM with imbedded rational polynomial coefficients (RPCs) to rapidly orthorectify raw non-terrain corrected data. As of mid – 2012 we estimate that > 4 petabytes (4 million gigabytes) of global data currently exist in WARP with much more data available through USGS CIDR requests.

How to Query Vendor Archives

The complete data collection archives of DigitalGlobe (digitalglobe.com) and GeoEye (geooeye.com) can be searched online with their respective user search and discovery tools. Metadata are available including cloud coverage estimates, corner coordinates, and reduced resolution quick-look images. Cross-referencing archives is difficult as data file naming conventions are not consistent between vendor archives and WARP. If insufficient data are found within WARP, users are encouraged to search vendor archives. If data are found in the vendor archives that are not in WARP, a USGS CIDR request should be submitted. Using CIDR directly would waste limited available resources and is counterproductive to NGA's CQI distribution goals.

GeoEye has many search options available through GeoFUSE tools (http://geofuse.geoeye.com). Users can access online maps, use advanced options, such as searching with areas of interest (AOIs) using ESRI Shapefiles or a Google Earth keyhole markup language (KML). Geoeye's online resource center also provides up to date compressed Esri Shapefiles of IK-2 and GE-1 acquisition coverage freely available for download (http://geofuse.geoeye.com/resources/Default.aspx) that includes metadata information for archive searches. DigitalGlobe data can be searched using a web interface called image finder (http://browse.digitalglobe.com/imagefinder/main.jsp?), where users can search with a map display for their area of interest or upload an ESRI Shapefile. Note that imagery is dynamic and is in constant state of update.

Earth Science Applications of Sub-Meter Satellite Data

Examples of CQI data use are abundant in the earth science community. This resource provides many opportunities to understand sub-pixel phenomena that occur in other freely available moderate to coarse resolution satellite data used in earth science remote sensing applications. The primary use of data have been for validation of Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) land products for sub-pixel analysis, although the capabilities of CQI data have been used in other unique and novel ways due to the benefits of sub-meter resolution. We provide examples here of how these data have been recently used.

Many different forest applications of CQI include species identification [*Han et al.*, 2012]; crown delineation [*Palace et al.*, 2008]; plot-level tree height coupled with lidar data [*St-Onge et al.*, 2008]; canopy surface model generation [*Baltsavias et al.*, 2008]; forest health monitoring [*Wulder et al.*, 2012]; monitoring protected areas [*Soares et al.*, 2011]; and disturbance assessment from insects [*Wulder et al.*, 2009] and storms [*Romer et al.*, 2012].

CQI data were used for coastal zone for surveys of mangroves [*Satyanarayana et al.*, 2011]; benthic community mapping [*Roelfsema and Phinn*, 2010]; bathymetric mapping [*McCarthy et al.*, 2011]; and wetland pattern analysis [*Peregon et al.*, 2009] integrated with measurements of CH4 exchange [*Flessa et al.*, 2008].

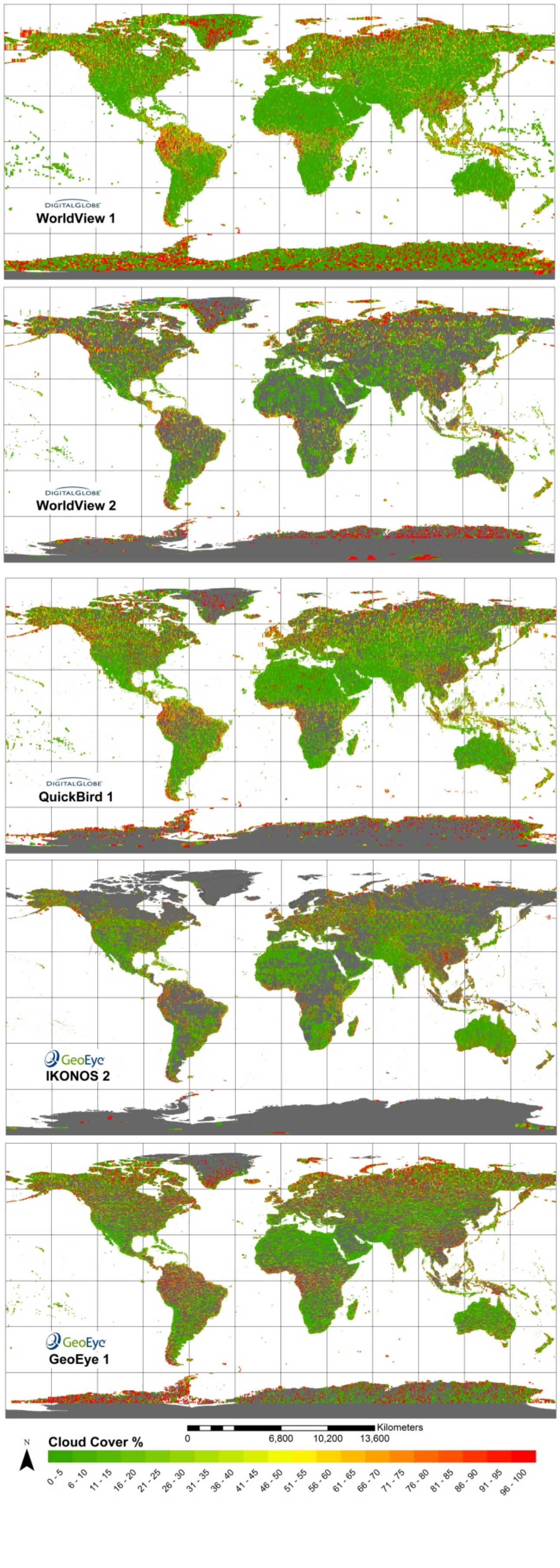
CQI data have been used for Cryosphere studies mapping changes in glacier extend in the high Alps [*Paul et al.*, 2011]; permafrost extent in the Mackenzie River Delta [*Nguyen et al.*, 2009]; monitoring rates of Arctic coastal erosion from melting ground ice [*Lantuit and Pollard*, 2008]; distribution of vertical meltwater conduits (moulin) in West Greenland [*Phillips et al.*, 2011]; and monitoring Weddle seals abundance and population trends in remote Erebus Bay, Antarctica [*LaRue et al.*, 2011].

Data have also been used for human-environment monitoring with urban land-cover delineation/characterization [*Huang and Zhang*, 2012]; urban disaster assessment in Haiti [*Kazama and Guo*, 2010]; cropland type mapping [*Upadhyay et al.*, 2012]; infectious disease monitoring by larval habitat mapping for malaria transmission [*Krefis et al.*, 2011]; archeology mapping of Neolithic settlements [*Alexakis et al.*, 2009]; and humanitarian aid decision support mapping of internally displaced persons (IDPs) camps in Southern Darfur [*Jenerowicz et al.*, 2011] and Sri Lanka [*Kemper et al.*, 2011].

Current WARP Development and Future Opportunities

Recent applications of CQI data have been highlighted, and additional unforeseen applications could be revealed in the future as data are used by more of the scientific community. As the data archive grows, multi-temporal high-resolution analysis becomes a possibility. Improvements to the WARP interface are ongoing and speed of access to query and retrieve more data volume will evolve. Graphical user interfaces (GUI's) are currently under development using an interface similar to Google Earth. The release date of these interfaces to users outside of NGA is still to be determined. Note the current WARP system has limitations; large areas (> 500 x 500 km) can be difficult and time consuming to search and discover data. This is due to limited download rates from WARP servers (~1 image per hour from 9 AM - 5 PM), and maximum results returned for each search < 250.

Commercial remote sensing industry growth has been rapid from the onset of NGA's contracts. New instruments will be launched in 2013 that have greater resolution and image acquisition capacity, ushering in the next era of CQI. These data provided by NGA at no charge via license agreement with U.S. commercial vendors is a vast resource available to qualified image analysts and Earth scientists that have yet to reveal their full benefit to the research community.



U.S. commercial sub-meter image archives from GeoEye and DigitalGlobe displayed as color coded cloud cover percentage by individual image bounds by sensor. Overlapping bounds show earliest image acquisition from the archive and data is primarily post 2007.

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